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SYSTEMATIC REVIEW

Effect of Repetition Duration During Resistance Training on Muscle Hypertrophy: A Systematic Review and Meta-Analysis

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Abstract
Background Maximizing the hypertrophic response to resistance training (RT) is thought to be best achieved by proper manipulation of exercise program variables including exercise selection, exercise order, length of rest intervals, intensity of maximal load, and training volume. An often overlooked variable that also may impact muscle growth is repetition duration. Duration amounts to the sum total of the concentric, eccentric, and isometric components of a repetition, and is predicated on the tempo at which the repetition is performed.
Objective We conducted a systematic review and meta-analysis to determine whether alterations in repetition duration can amplify the hypertrophic response to RT.
Methods Studies were deemed eligible for inclusion if they met the following criteria: (1) were an experimental trial published in an English-language refereed journal; (2) directly compared different training tempos in dynamic exercise using both concentric and eccentric repetitions; (3) measured morphologic changes via biopsy, imaging, and/or densitometry; (4) had a minimum duration of 6 weeks; (5) carried out training to muscle failure, defined as the inability to complete another concentric repetition while maintaining proper form; and (6) used human subjects who did not have a chronic disease or injury. A total of eight studies were identified that investigated repetition duration in accordance with the criteria outlined.
Results Results indicate that hypertrophic outcomes are similar when training with repetition durations ranging from 0.5 to 8 s.
Conclusions From a practical standpoint it would seem that a fairly wide range of repetition durations can be employed if the primary goal is to maximize muscle growth. Findings suggest that training at volitionally very slow durations (>10s per repetition) is inferior from a hypertrophy standpoint, although a lack of controlled studies on the topic makes it difficult to draw definitive conclusions.

Key Points

Hypertrophic outcomes appear to be similar when training with repetition durations ranging from 0.5 to 8 s to concentric muscular failure, suggesting that a fairly wide range of repetition durations can be employed if the primary goal is to maximize muscle growth.

Limited evidence suggests that training at volitionally very slow durations (>10 s per repetition) is inferior from a hypertrophy standpoint, although a lack of controlled studies on the topic makes it difficult to draw definitive conclusions.

It is not clear whether combining different repetition durations would enhance the hypertrophic response to resistance training.

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1 Introduction

It has been well-established that regimented resistance training (RT) is an effective means to increase skeletal muscle mass. The regular performance of progressive RT positively mediates intracellular anabolic signaling, shifting protein balance to favor synthesis over degradation. Over time, the summation of these responses results in the net accretion of contractile proteins, leading to increased muscle thickness via sarcomeres added in parallel [1]. The magnitude of muscular gains can be substantial even over the short-term, with increases in cross-sectional area (CSA) of more than 50 % reported after just 16 weeks of regimented RT [2].

Maximizing the hypertrophic response to RT is thought to be best achieved by proper manipulation of exercise program variables [3]. Primary RT variables that are frequently manipulated include exercise selection, exercise order, length of rest intervals, intensity of maximal load, and training volume [3]. However, an often overlooked variable that also may impact muscle growth is repetition duration. Duration amounts to the sum total of the concentric, eccentric, and isometric components of a repetition, and is predicated on the tempo at which the repetition is performed. Tempo is frequently expressed in a three-digit arrangement where the first number is the time (in seconds) to complete the concentric action, the second number is the isometric transition phase between concentric and eccentric actions, and the third number is the time to complete the eccentric action [4]. For example, a tempo of 1–0–2 would indicate a lift taking 1 s on the concentric action, no pause at the top of the movement, and 2 s on the eccentric action. In the preceding example the overall repetition duration would be 3 s. It should be noted that the majority of studies focus only on the concentric and eccentric actions, neglecting to include an isometric component.

To an extent, repetition duration will be dependent on the intensity of load. The use of very heavy loads [more than ~85 % of 1 repetition maximum (RM)] will necessitate an all-out effort to concentrically move the load quickly, but the actual velocity of the lift will be relatively slow. Moreover, concentric repetition velocity will be reduced even further as a set approaches the point of muscular failure due to an inability of working fibers to maintain force output. Mookerjee and Ratamess [5] demonstrated that the first concentric repetition of a 5 RM bench press took 1.2 s to complete while the fourth and fifth repetitions took 2.5 and 3.3 s, respectively. These results were seen despite subjects attempting to move the weight as quickly as possible.

On the other hand, when lifting submaximal loads of ~80-85 % of 1 RM and lighter an individual has the ability to vary the concentric tempo of lifting. Given that eccentric strength is approximately 20–50 % greater than concentric strength [6], the velocity of eccentric actions can be altered at loads in excess of concentric 1 RM. It has been postulated that intentionally slowing repetition cadence reduces the momentum in a lift, thereby increasing the tension on a muscle [7]. Hypothetically, increasing mechanical tension throughout a lift could positively mediate intracellular anabolic signaling, promoting a greater hypertrophic response. Despite a logical rationale, however, it is unclear from the literature whether intentional alterations in tempo amplify the hypertrophic response to RT. Current research on the topic has produced mixed findings, and the methodologies of the studies have been disparate. The purpose of this paper, therefore, is to conduct a systematic review and meta-analysis as to the effects of repetition duration on muscle growth in an effort to provide clarity on the topic.

2 Methods

2.1 Inclusion Criteria

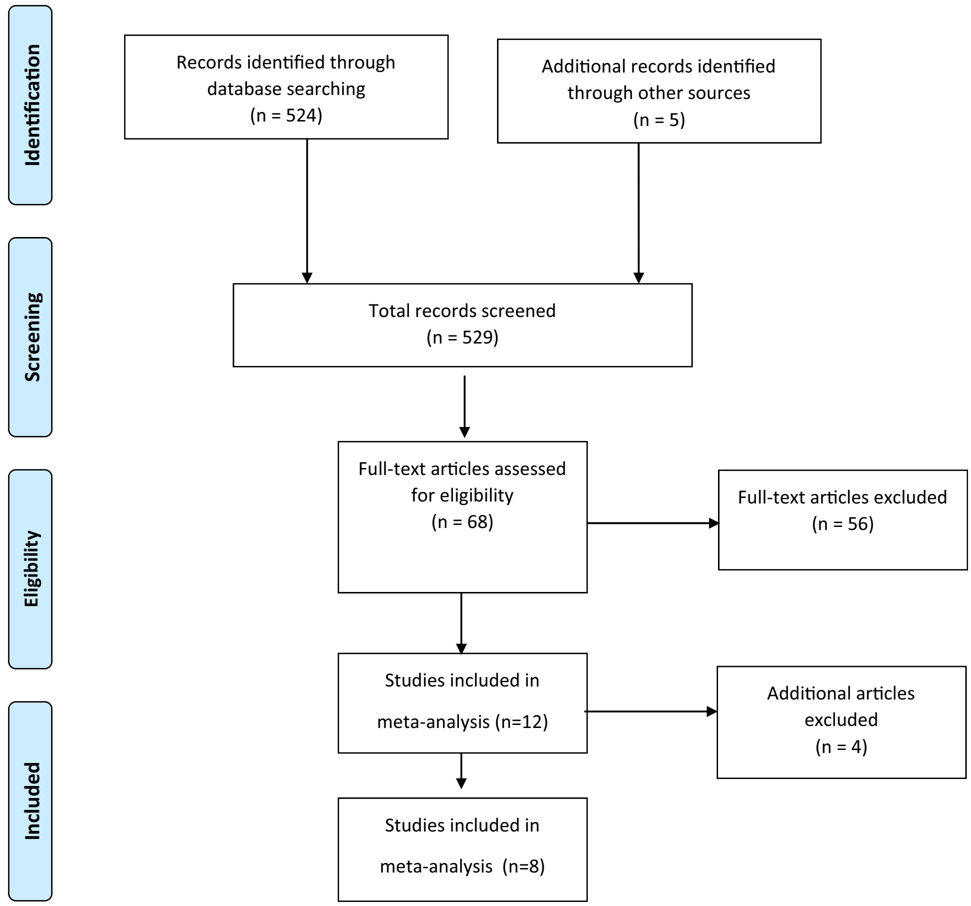
Studies were deemed eligible for inclusion if they met the following criteria: (1) were an experimental trial published in an English-language refereed journal; (2) directly compared different training tempos in dynamic exercise using both concentric and eccentric repetitions; (3) measured morphologic changes via biopsy, imaging, and/or densitometry; (4) had a minimum duration of 6 weeks; (5) carried out training to muscle failure, defined as the inability to complete another concentric repetition while maintaining proper form; and (6) used human subjects who did not have a chronic disease or injury.

2.2 Search Strategy

To carry out this review, English-language literature searches of the PubMed and EBSCO databases were conducted from all timepoints up until April 2014. Combinations of the following keywords were used as search terms: "muscle"; "hypertrophy"; "growth"; "cross sectional area"; "duration"; "tempo"; "cadence"; "velocity"; "speed"; "resistance training"; "resistance exercise"; and "repetitions". After conducting the initial search, the reference lists of articles retrieved were then screened for any additional articles that had relevance to the topic, as described by Greenhalgh and Peacock [8].

A total of 529 studies were evaluated based on search criteria. To reduce the potential for selection bias, each of these studies were independently perused by two of the

Fig. 1 Flow diagram of search process



investigators (B.J.S. and D.I.O.), and a mutual decision was made as to whether or not they met basic inclusion criteria. Any inter-reviewer disagreements were settled by consensus and/or consultation with the third investigator. Of the studies initially reviewed, 68 were determined to be potentially relevant to the paper based on information contained in the abstracts. Full text of these articles was then screened and 12 were identified for possible inclusion in the paper. After consensus amongst the investigators, four additional studies were excluded because either (1) both groups did not train to failure [9, 10–11], or (2) imaging modalities were not used to measure body composition [12]. A total of eight studies were ultimately identified for inclusion in accordance with the criteria outlined (see Fig. 1). One of these studies [13] used previously collected data so its data was combined with that of the original study [14] for analysis. Table 1 summarizes the studies included for analysis.

2.3 Coding of Studies

Studies were read and individually coded by two of the investigators (B.J.S. and D.I.O.) for the following variables: descriptive information of subjects by group including sex, body mass index, training status (trained subjects were defined as those with at least 1 year of regular RT experience), age, and stratified subject age [classified as either young (18–29 years), middle-aged (30–49 years), or elderly (50+ years)]; whether the study was a parallel or within-subject design; the number of subjects in each group; duration of the study; repetition duration based on stratified repetition range [classified as either fast/heavy (sets of 6–12 with a total repetition duration of 0.5–4 s), fast/light (sets of 20–30 with a total repetition duration of 0.5–4 s), medium (sets of 6–12 with a total repetition duration of 4–8 s), or slow (sets of 6–12 with a total repetition duration of >8 s)]; exercise volume (single set, multi-set, or both); whether volume was equated between groups; speed of concentric action; speed of eccentric action; type of morphologic measurement [magnetic resonance imaging (MRI), computerized tomography (CT), ultrasound, biopsy, dual energy x-ray absorbtiomety (DXA), and/or densitometry] and; region/muscle of body measured (upper, lower, or both). Coding was cross-checked between coders, and any discrepancies were resolved by mutual consensus. To assess potential coder drift, 30 % of the studies were randomly selected for recoding as described by Cooper et al. [15]. Per case

Table 1 Studies meeting inclusion criteria

References	Subjects/protocol	Rep duration (s)	Measurement modality	Results
Claflin et al. [26]	63 young and old untrained men and women randomized to either a high-velocity (hip 250–350 d/s, knee 100–160 d/s) or low-velocity (hip 30–90 d/s, knee 20–40 d/s), 2 × 10, 1 × fail (5–15 reps) RT protocol carried out 3×/week for 14 weeks	0.5–0.66 vs. 1–2 vs. 2–6 vs. 4–8	Biopsy	No effect of training on type 1 fibers, 8.2 % increase in type 2 irrespective of tempo
Keeler et al. [27]	14 healthy, sedentary women, 19–45 years, randomized to either superslow or traditional Nautilus RT protocol for 10 weeks	6 vs. 15	BodPod	No significant differences in body composition
Neils et al. [28]	16 healthy untrained men and women randomized to either superslow at 50 % 1 RM or traditional RT at 80 % 1 RM for 8 weeks	6 vs. 15	DXA	No significant differences in body composition
Rana et al. [14]	34 untrained young females randomized to either a moderate intensity (80–85 % RM) at a tempo of 1–2 s, a low intensity (~40–60 % 1 RM) at a tempo of 1–2 s, or slow-speed (~40–60 % 1 RM) at a tempo of 10 s concentric and 4 s eccentric for 6 weeks	2–4 vs. 14	BodPod	Main effect training of FFM, no effect by group (exclude)
Schuenke et al. [13]	34 untrained young women randomly assigned to either moderate intensity (80–85 % RM) at a tempo of 1–2 s, a low intensity (~40–60 % 1 RM) at a tempo of 1–2 s, or slow-speed (~40–60 % 1 RM) at a tempo of 10 s concentric and 4 s eccentric for 6 weeks	2–4 vs. 14	Biopsy	Significantly greater increases in CSA for faster vs. slower tempo
Tanimoto and Ishii [24]	24 untrained young men randomly assigned to either 50 % RM with a 6 s tempo and no relaxing phase between rep, 80 % RM with a 2 s tempo and 1 s relaxation between reps, or 50 % RM with a 2 s tempo and 1 s relaxation between reps for 12 weeks	2 vs. 6	MRI	No significant differences in muscle CSA
Tanimoto et al. [23]	36 untrained young men (12 served as non-exercising controls) randomly assigned to either 55–60 % 1 RM with a 6 s tempo and no relaxing phase between reps or 80–90 % RM with a 2 s tempo and 1 s relaxation between reps. Exercise consisted of 3 sets of squat, chest press, lateral pulldown, abdominal bend, and back extension, performed 2 days a week for 13 weeks	2 vs. 6	Ultrasound	No significant differences in muscle thickness
Young and Bilby [25]	18 untrained males randomized to either perform fast concentric contractions or slow controlled movements for 7.5 weeks	2 vs. 4–6	Ultrasound	No significant differences in muscle thickness

CSA cross-sectional area, *d/s* degrees per second, *DXA* dual x-ray absorptiometry, *FFM* fat-free mass, *MRI* magnetic resonance imaging, *rep* repetition, *RM* repetition maximum, *RT* resistance training

agreement was determined by dividing the number of variables coded the same by the total number of variables. Acceptance required a mean agreement of 0.90.

2.4 Calculation of Effect Size

For each hypertrophy outcome, an effect size (ES) was calculated as the pre-test–post-test change, divided by the pre-test standard deviation (SD) [16]. The sampling variance for each ES was estimated according to Morris and DeShon [16]. Calculation of the sampling variance required an estimate of the population ES and the pre-test–post-test correlation for each individual ES. The population ES was estimated by calculating the mean ES across all studies and treatment groups [16]. The pre-test–post-test correlation was calculated using the following formula (Eq. 1) [16]:

$$r = \left(s_1^2 + s_2^2 - s_D^2\right)/(2\,s_1 s_2) \quad (1)$$

where s_1 and s_2 are the SD for the pre- and post-test means, respectively, and s_D is the SD of the difference scores. If s_D was not reported in the paper, the P value for the pre/post change was used to estimate it. If a threshold for significance was given rather than a specific value (such as $P < 0.05$), then that threshold was used in the calculation. If no P values were available for calculation, an upper bound on s_D was estimated using the following formula (Eq. 2):

$$s_D = \sqrt{\left(\left(s_1^2/n\right) + \left(s_2^2/n\right)\right)} \quad (2)$$

2.5 Statistical Analyses

Meta-analyses were performed using hierarchical linear mixed models, modeling the variation between studies as a random effect, the variation between treatment groups as a random effect nested within studies, the variation between within-group hypertrophy measures as a random effect nested within treatment groups, and the treatment group classification (slow, medium, fast heavy, fast light) as a fixed effect [17]. The within-group variances were assumed known. Observations were weighted by the inverse of the sampling variance [16]. Model parameters were estimated by the method of restricted maximum likelihood (REML) [18]. Denominator degrees of freedom (*df*) for statistical tests and confidence intervals (CIs) were calculated according to Berkey et al. [19]. One analysis was carried out on all data, and a separate analysis was carried out on only studies with a direct measure of hypertrophy. Due to inadequate studies with direct measurements of hypertrophy and a slow or fast light group, these categories were not analyzed in the subanalysis of studies with direct measures of hypertrophy. Adjustments for post hoc multiple comparisons among treatment categories were made using a Hochberg correction [20]. All analyses were performed using S-Plus® 8.2 (Tibco Spotfire®, Boston, MA, USA). Effects were considered significant at $P \leq 0.05$, and trends were declared at $P > 0.05 \leq 0.10$. Data are reported as $\bar{x} \pm$ standard error of the mean (SEM) values and 95 % CIs.

3 Results

3.1 Study Characteristics

The complete analysis comprised 204 subjects and 46 ESs, nested within 18 treatment groups and eight studies. The weighted mean ES across all studies and groups was 0.46 ± 0.13 (95 % CI 0.20–0.71). The subanalysis of studies with direct hypertrophy measurements comprised 113 subjects and 24 ESs, nested within eight treatment groups and four studies. The weighted mean ES across these studies and groups was 0.40 ± 0.15 (95 % CI 0.10–0.69).

3.2 Complete Model

The mean ES and CI for each tempo category can be seen in Fig. 2. The ES for fast/heavy duration was 0.67 ± 0.19 (95 % CI 0.22–1.13); the ES for the fast/light duration was 0.79 ± 0.37 (95 % CI 0.095–1.67); the ES for the medium duration was 0.27 ± 0.20 (95 % CI −0.22 to 0.75); the ES for the slow duration was 0.29 ± 0.27 (95 % CI −0.34 to 0.92). There were no significant differences between any of the tempo categories (Hochberg-adjusted *P* value = 0.94).

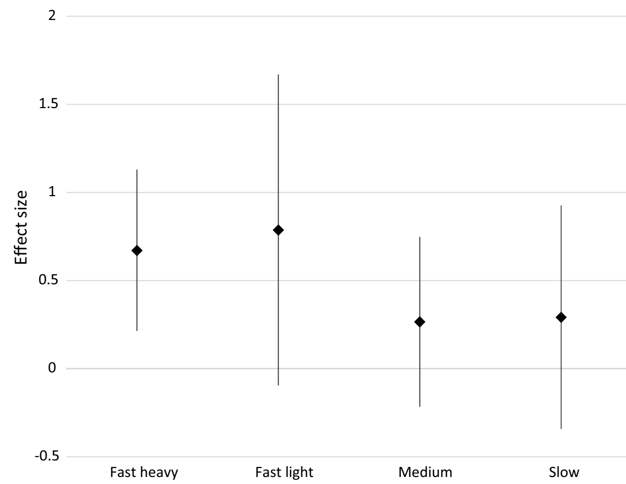


Fig. 2 Mean effect size and 95 % confidence interval for each tempo category

3.3 Model of Direct Hypertrophy Measurements

The mean ES and CI for each tempo category can be seen in Fig. 3. The ES for the fast/heavy duration was 0.42 ± 0.17 (95 % CI −0.10 to 0.95); the ES for the medium duration was 0.37 ± 0.17 (95 % CI −0.16 to 0.90). There was no significant difference between the fast/heavy and medium duration categories (*P* = 0.73).

4 Discussion

To the authors' knowledge, this is the first systematic review and meta-analysis to examine the effects of repetition duration on the hypertrophic response to RT. The meta-analysis of hypertrophy outcomes showed no significant differences between any of the training tempos evaluated. An initial analysis of all studies meeting inclusion criteria found that the fast/heavy and fast/light conditions had ESs of ~0.7 to 0.8, whereas the medium and slow conditions had ESs of ~0.3. Although these results would seem to suggest a trend for superiority in the faster speed groups, the CIs were quite wide, thereby indicating large variances within groups.

One potential confounding issue with studies meeting inclusion criteria is the disparate methods used to assess changes in muscle mass over time. These methods included both direct (MRI, ultrasound, and muscle biopsy) and indirect hypertrophic measures (DXA and air displacement plethysmography). Given that indirect assessments may not

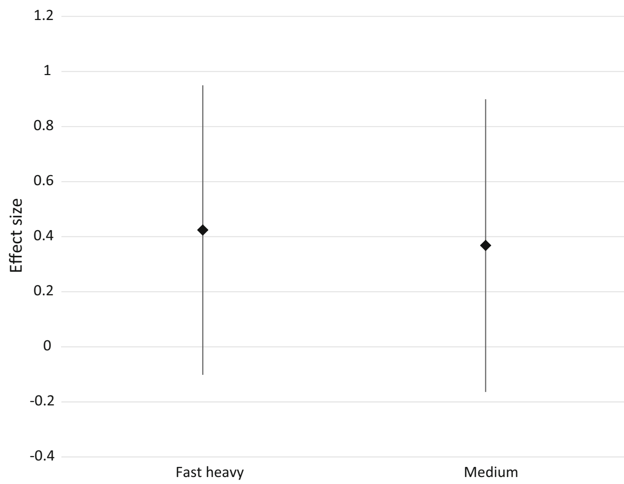


Fig. 3 Mean effect size and 95 % confidence interval for each tempo category: studies with direct hypertrophy measurements only

be sensitive enough to detect subtle differences in muscle mass over time [21], we performed a meta-regression that analyzed only studies employing direct methods of measurement. Results showed that differences in ES between fast/heavy and medium durations substantially narrowed after regression (0.42 vs. 0.37, respectively), and these differences were statistically insignificant ($P = 0.73$). The fast/light and slow groups were excluded from subanalysis since only one study investigated these conditions with direct imaging. Collectively, the data suggest that repetition duration does not significantly impact the hypertrophic response to RT, at least in the fast/heavy and medium conditions.

Research indicates that intentionally performing repetitions in a very slow manner does not provide an adequate stimulus for complete activation of a muscle's motor unit pool. Employing a within-subject design, Keogh et al. [22] recruited 12 young experienced lifters to perform one set of the bench press using a variety of training methods including a very slow cadence and a traditional cadence. The slow lifting condition performed the exercise at 55 % of 1 RM for a total duration of 10 s per repetition (5 s for both concentric and eccentric actions); the traditional training condition was performed at ~85 % of 1 RM with the intent to lift the weight as fast as possible. Each condition was carried out to the point of concentric muscular failure. Compared with very slow lifting, mean concentric electromyographic (EMG) activity of the pectoralis major was significantly higher during traditional training by ~18, 19, and 12 %, for the first, middle, and last repetition, respectively. The disparity was even greater during eccentric actions, with a significantly greater mean EMG activity of 32, 36, and 36 % in the first, middle, and last repetition, respectively, reported for traditional compared with superslow training. Given that recruitment is necessary to induce an adaptation in a muscle fiber, these results suggest an impaired hypertrophic response in the slow lifting condition. Indeed, Schuenke et al. [13] evaluated fiber-type specific changes in CSA in superslow versus traditional RT protocols. Young, untrained female subjects carried out multiple sets of the squat, leg press, and leg extension exercises 2–3 days a week for 6 weeks. The superslow group performed 6–10 RM per set (equating to ~40–60 % of 1 RM) at a concentric velocity of 10 s and an eccentric velocity of 4 s. The traditional training group performed the same 6–10 RM per set (equating to ~80–85 % of 1 RM) at a concentric and eccentric velocity of 1–2 s. Post-study increases in hypertrophy of type IIa and type IIx fibers were markedly higher in the traditional training group (~33 and 37 %, respectively) than in the superslow group (~12 and 19 %, respectively). Moreover, a markedly greater decrease in total type IIx fiber area was noted in the traditional than in the superslow (~39 versus 28%, respectively) group, along with a significantly greater increase in total type IIa fiber area (~30 vs. 11 %, respectively), indicating that very slow lifting failed to sufficiently stimulate the highest threshold motor units. The totality of these findings suggests that training at very slow speeds is suboptimal for maximizing gains in muscle hypertrophy, presumably as a result of inadequate motor unit recruitment and stimulation. This outcome may be due at least in part to the need to substantially reduce intensity of load during volitionally very slow lifting to equate the number of repetitions performed at faster tempos.

As previously mentioned, it is important to consider the measurement instruments employed when attempting to draw evidence-based conclusions. Five studies directly measured local hypertrophic changes in the trained musculature. Of the five studies, three investigated changes in muscle CSA by either MRI or ultrasound [23–24, 25]. No significant differences in hypertrophy were seen in any of these studies. It should be noted, however, that the study by Tanimoto et al. [23] showed ~34 % greater absolute increases in muscle thickness in the fast than in the slow condition. The small sample size of the study suggests that the lack of significance may be attributed to a type II error. Moreover, the overall duration of the fast and slow conditions in the three studies varied from 2–3 to 4–6 s per repetition, respectively. Thus, it might be concluded that any hypertrophic differences within this fairly narrow range, if they do in fact occur, will be subtle.

The other two studies that directly assessed hypertrophy did so via muscle biopsy and produced contradictory findings [13, 26]. Schuenke et al. [13] found a markedly greater increase in total mean fiber CSA for traditional versus superslow training (~39 vs. ~11 %, respectively). Conversely, Claflin et al. [26] showed velocity of training had no effect on increases in fiber area. Although

speculative, these results can seemingly be attributed to differences in total repetition duration for the slow training conditions. With respect to Schuenke et al. [13], repetition duration in the slow condition was 14 s while that for Claflin et al. [26] was 2–8 s. It can therefore be speculated that a threshold for velocity may exist beyond which gains in muscle hypertrophy are impaired, and that the superslow protocol employed by Schuenke et al. [13] exceeded this threshold. This hypothesis warrants further study. It also should be noted that the study by Claflin et al. [26] was carried out under isokinetic conditions, which may induce differences in muscular adaptations compared to traditional dynamic exercise.

Three of the studies did not directly assess site-specific changes in muscle growth and instead employed measures of overall fat-free mass (FFM) (i.e., DXA and densitometry) [14, 27, 28]. Although such measures provide a general estimate of hypertrophic gains over the course of a RT study, they nevertheless lack the sensitivity to assess subtle changes in muscle mass [21]. In addition to skeletal muscle, FFM also includes such components as body fluids, bone, collagen, and other non-fatty tissues. Thus, it cannot be concluded that changes in FFM are specific to muscle hypertrophy. All of the studies in question compared superslow training with traditional lifting velocities; two of these studies [27, 28] were not able to detect significant differences in FFM from baseline to post-study in any of the conditions investigated. Given that results of studies directly measuring hypertrophy all showed significant hypertrophic gains at least in the faster training velocities if not all velocities tested [13, 23–24–26], it seems counter-intuitive that subjects in the studies by Keeler et al. [27] and Neils et al. [28] did not experience increases in muscle hypertrophy over the course of a supervised 8- to 10-week RT program. The other study by Rana et al. [14] showed significant increases in FFM from baseline to post-study in all conditions including a non-exercising control. Curiously, the control condition experienced similar FFM gains to the traditional and superslow training groups (1.9 vs. 2.2 and 2.0 %, respectively) despite remaining sedentary throughout the 6-week study period. Results of these studies therefore need to be interpreted circumspectly when attempting to draw evidence-based conclusions on the hypertrophic effects of training velocity.

A limitation of this review is that the included studies did not address whether altering the time spent in specific phases of contraction (eccentric vs. concentric) during the repetition evoked any hypertrophic advantage. Shepstone et al. [29] demonstrated a trend for enhanced hypertrophy with faster isokinetic eccentric contractions (3.66 vs. 0.35 rad/s) and Farthing et al. [30] found that fast isokinetic (3.14 rad/s) eccentric actions promoted greater overall change in muscle thickness than both slow (0.52 rad/s) and fast concentric actions, but not slow eccentric actions. These studies tentatively support a hypertrophic superiority for faster eccentric tempos under isokinetic conditions. It is important to note, however, that such results may not be applicable to the more commonly utilized dynamic training methods with coupled concentric and eccentric actions. Gillies et al. [31] compared prolonged eccentric (6–1–2–1) with concentric phases (2–1–6–1) using dynamic training with both conditions matched for total time-under-load. At the conclusion of 9 weeks of training there was comparable hypertrophy of type I fibers between the groups, but the slower concentric group increased hypertrophy of type II fibers to a greater extent than the slow eccentric group despite equivalent whole-muscle growth as assessed by thigh circumferences. Further research is required to draw a firm conclusion on any differential effects of altered eccentric or concentric tempos with respect to muscle hypertrophy.

In addition, the results of the present study must be considered in the context of training to the point of concentric failure, and therefore may not necessarily be generalized to training when sets are terminated prior to this point. In applying this criterion a study by Nogueira et al. [9] was excluded from the meta-analysis. The authors compared slow concentric phase (3–0–3–0) with fast concentric phase (3–0–1–0) training using matched work outputs in elderly men. After 10 weeks, muscle thickness was only increased in the rectus femoris with the faster concentric tempos, while both tempo conditions resulted in growth in the biceps brachii, statistically favoring faster concentric training. Recent studies have demonstrated that when taken to the point of concentric failure, muscle growth is comparable regardless of the training intensity utilized [32, 33]. These findings are consistent with the premise that fatigue reduces motor unit recruitment thresholds, thereby enhancing muscle recruitment [34]. It is therefore possible that the utilization of concentric muscular failure in training may negate the impact of, or equate the effect of, different repetition durations such that muscle growth is ultimately similar between conditions. Further research is required to clarify the role of tempo in exercise prescriptions to promote muscle hypertrophy when training short of concentric muscular failure.

In addition, there was substantial variation in the methodology utilized across studies that may at least partially explain the disparity between studies and, consequently, the large CIs seen in the present dataset. While the present study sought to minimize the impact of experimental designs by choosing studies that utilized a common set endpoint (concentric muscular failure), there was great variety in other experimental parameters. Whilst repetition durations varied over a wide range across studies, the use of differing training intensities, sexes, age groups, and

measurement techniques likely contributed to the heterogeneous nature of the literature base.

Finally and importantly, the utilization of untrained subjects limits the generalizability of our findings to trained populations. Long-term RT has been shown to alter both the structure and function of skeletal muscle [35–38–39] and impacts the acute anabolic signaling, protein synthetic and transcriptional responses to RT [40–41–43]. Therefore, it may be possible that differential hypertrophic responses may occur in trained muscle in response to varying repetition tempos.

5 Conclusion

Current evidence indicates that hypertrophic outcomes are similar when training with repetition durations ranging from 0.5 to 8 s to concentric muscular failure. Thus, from a practical standpoint it would seem that a fairly wide range of repetition durations can be employed if the primary goal is to maximize muscle growth. Results suggest that training at volitionally very slow durations (>10 s per repetition) is inferior from a hypertrophy standpoint, although a lack of controlled studies on the topic makes it difficult to draw definitive conclusions. It is not clear if combining different repetition durations would enhance the hypertrophic response to RT. This possibility requires further study.

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Conflict of interest None.

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